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(54) IMPROVEMENTS IN OR RELATING TO FUEL INJECTION SYSTEMS

(71) We, THE PLESSEY COMPANY LIMITED, a British Company, of 2/60 Vicarage Lane, Ilford, Essex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to fuel injection systems.

The invention is concerned especially with a fuel injection system for internal combustion engines comprising a fuel injection nozzle including an orifice and an obturating member which is effective normally to seal the orifice to prevent fluid flowing through the nozzle, a piezoelectric transducer operatively associated with the nozzle, and an oscillator for driving the transducer so as to cause the obturating member to vibrate thereby to permit of fluid flow through the nozzle when the transducer is driven. For the purpose of controlling the amount of fuel fed through the nozzle the signal fed to the transducer may be a pulse signal comprising signal bursts from the oscillator so that fuel flows from the nozzle only contemporaneously with a pulse. One problem with this system is to ensure that ringing effects which prolong vibration of the obturating member after cessation of the driving pulse are obviated or at least significantly reduced. This is particularly important when precise fuel monitoring is required since quite clearly fuel flow after cessation of a pulse cannot be tolerated especially when pulse lengths are short as required for slow speed operation of an internal combustion engine fed from the system.

According to the present invention a fuel injection system comprises a fuel injection nozzle including an orifice and an obturating member which is effective normally to seal the orifice to prevent fluid flowing through the nozzle, a piezo-electric transducer operatively associated with the nozzle, and an oscillator for driving the transducer so as to cause the obturating member to vibrate thereby to permit in use fluid flow through the nozzle when the transducer is thus driven, the oscillator having associated with it switch means effective for cutting off the drive signal from the oscillator to the transducer, so that after switch off the impedance presented to the transducer is not less than its own impedance.

In this way ringing effects which can prolong vibration of the obturating member after cessation of oscillator drive are obviated or significantly reduced.

The obturating member may be a ball and the nozzle may be fabricated to define a resonant horn. A suitable nozzle is fully described in our G.B. Patent No. 1,420,313. The oscillator may comprise a bridge circuit one arm of which includes the transducer one side of the bridge being fed from an amplifier via a transformer so as to produce across the other opposite side of the bridge a feedback voltage which is fed via a feedback line to the amplifier.

The switch means may comprise a semiconductor switch which forms a part of the amplifier.

In order to balance statically, the bridge the transducer may be shunted by a capacitor which may be variable. In order to facilitate starting, the transducer may also be shunted by a resistor. One resistive arm of the bridge may be shunted by a capacitor, and a resistor in the feedback line may be shunted by a capacitor.

With this arrangement, the capacitor which shunts the resistive arm of the bridge unbalances the bridge to facilitate easy starting of the oscillator because a positive feedback voltage produced is increased by the bridge unbalance and the resistor which shunts the transducer has a similar effect. In

order to compensate for the phase shift introduced by this capacitor a further capacitor may be introduced into the feedback line.

The switch may include a transistor which is normally conductive to provide a low impedance path at the input of the amplifier to inhibit oscillation but which ceases conducting consequent upon the application thereto of a control pulse to permit oscillation. The transistor may be shunted by a zener diode which is arranged to operate when the transistor is non-conductive so as to provide a stable bias current for the input transistor of the amplifier.

An exemplary embodiment of the invention will now be described with reference to the accompanying drawing which is a circuit diagram of an oscillator arranged to feed a transducer.

Referring now to the drawing the oscillator is arranged to feed a transducer 1. The transducer is operatively associated with a fuel injection nozzle (not shown) which is of the type including a ball normally biassed in sealing engagement against a valve seat by fuel pressure. When the transducer is driven with ultrasonic energy, the ball is caused to vibrate so as to lift from the seat to admit fuel to an inlet manifold or a combustion chamber. The transducer 1 and its associated shunt capacitor 1*a* and shunt resistor 1*b* form one arm of a bridge circuit the other arms being defined by the capacitor 2, the resistor 3 and the parallel combination of the resistor 4 and the capacitor 5. The bridge is fed from the secondary winding of a transformer 6 the primary winding of which is fed from a pair of transistors 7 and 8 which operate as an amplifier. In operation of the circuit the bridge is fed at one side from the secondary winding of the transformer 6 and a voltage developed across the other side and appearing at the junction between the components 2 and 3 is fed on a feedback line 9, which includes a parallel combination of a resistor 10 and a capacitor 11, to the base of the transistor 8 which constitutes the input of the amplifier. In order to facilitate pushed operation of the oscillator as would be required to provide the operation of the oscillator as would be required to provide the necessary bursts of energy to the transducer 1, it is arranged that a switching transistor 12 which is normally conductive is connected to the base of the transistor 8 to inhibit oscillation. The transistor 12 which is fed with a control pulse from line 13 via a further transistor 14 is switched off when the pulse is applied and the voltage at the point 15 rises to the breakdown voltage of a zener diode 16 which turns on transistors 7 and 8 and this enables the oscillator to start.

It will be appreciated that in normal operation the oscillator would be switched on and off continuously the length of the 'ON' period determining the amount of fuel which is fed to the engine with which the system is associated. Since the impedance of the transducer 1 varies in accordance with its operative condition, starting can sometimes be difficult and to facilitate starting the capacitor 5 is included which shunts the resistor 4 in one arm of the bridge to create an out of balance condition which in turn results in a large feedback voltage on the line 9 which rapidly initiates oscillation, and resistor 1*b* serves the same purpose. This starting capacitor 5 introduces undesirable phase shifts and to remove the effect of the phase shift the feedback resistor 10 is shunted by the capacitor 11. The bridge is balanced by suitable choice of capacitor 1*a*. The arrangement shown is of a system including only one transducer by a number of transducers, as may be required in a multi cylinder engine may be fed from the oscillator according to the invention.

One very important advantage of the system described is that after cessation of a drive pulse the transducer 1 does not 'ring' significantly since it is arranged on switch off to 'look into' a relatively high impedance. In practice this impedance is comparable to its own impedance in the non-operative condition and approximates to 4KΩ. During operation however, the impedance falls to about 2KΩ. This relatively high impedance of 4KΩ at switch on can impede oscillator starting and so the shunt resistor 1*a* is used as herebefore described. The shunt capacitor 1*b* plus the capacitance of the transducer 1 is arranged to be equal to the capacitance of the capacitor 2. In practice the transducer has a capacitance of about 620pf, the capacitance of the capacitor 2 is 820pf and so the capacitance of capacitor 1*b* is about 200pf. These values are of course dependent on the choice of transducer and may vary with operating frequency which in the present case is 60 KHz.

WHAT WE CLAIM IS:-

1. A fuel injection system comprising a fuel injection nozzle including an orifice and an obturating member which is effective normally to seal the orifice to prevent fluid flowing through the nozzle, a piezoelectric transducer operatively associated with the nozzle and an oscillator for driving the transducer so as to cause the obturating member to vibrate thereby to permit in use fluid flow through the nozzle when the transducer is thus driven, the oscillator having associated with it switch means effective for cutting off the drive signal from the oscillator to the transducer so that after switch off the impedance presented to the transducer is not less than its own impedance.

2. A fuel injection system as claimed in claim 1, wherein the obturating member is a

ball and the nozzle is fabricated to define a resonant horn.

3. A fuel injection system as claimed in claim 1 or claim 2, wherein the oscillator comprises a bridge circuit one arm of which includes the transducer, one side of the bridge being fed from an amplifier via a transformer so as to produce across the other opposite side of the bridge a feedback voltage which is fed via a feedback line to the amplifier.

4. A fuel injection system as claimed in any preceding claim wherein the switch means comprises a semiconductor switch which is operatively associated with the amplifier.

5. A fuel injection system as claimed in any preceding claims, wherein the transducer is shunted by a capacitor.

6. A fuel injection system as claimed in any preceding claims, wherein the transducer is shunted by a resistor.

7. A fuel injection system as claimed in any one of claims 3 to 6 wherein one arm of the bridge circuit comprises a resistor and a capacitor connected in parallel.

8. A fuel injection system as claimed in any one of claims 3 to 7 wherein the feedback line includes the parallel combination of a resistor and capacitor connected in series with the said line.

9. A fuel injection system as claimed in any one of claims 4 to 8 wherein the switch comprises a transistor which is adapted to be normally conductive to produce a low impedance path at the input of the amplifier thereby to inhibit oscillation but which is adapted to cease conducting consequent upon the application thereto of a control input thereby to allow oscillation, the transistor being shunted by a zener diode which, when the transistor is non-conductive operates so as to provide a stable bias current for an input transistor of the amplifier.

10. A fuel injection system including an oscillator substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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For the Applicants.

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1 SHEET This drawing is a reproduction of the Original on a reduced scale